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External Event Evaluations for the Design Phase PRA of Hanhikivi 1

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Agenda

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- Event identification and categorization
- Probability evaluation
- Event combinations
- Design values
- Hanhikivi 1 external event PRA
- Summary and conclusions

Fennovoima's Hanhikivi 1 project

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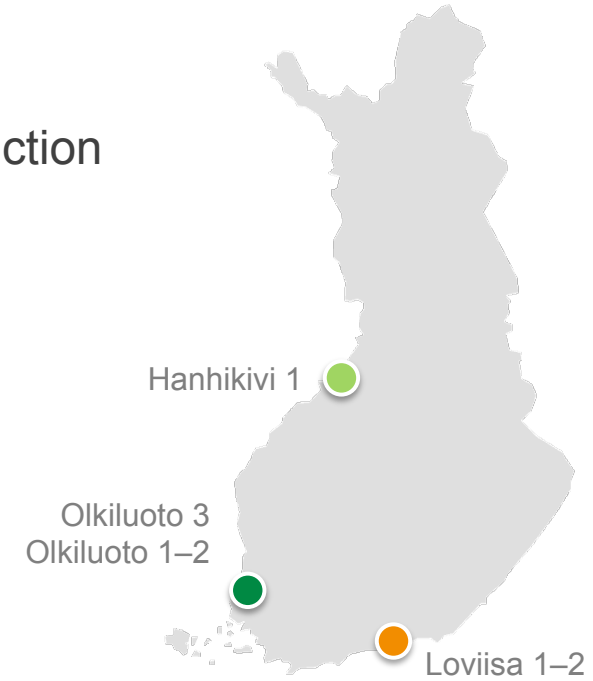
- The sixth nuclear power plant unit in Finland
- Project is in the design phase, target to get the construction license in 2019
- VVER-1200 (AES-2006) reactor, supplied by Rosatom

Thermal power of reactor	3200 MW
Thermal efficiency	~37 %
Electric power	1200 MW
Number of primary loops / steam generators	4
Sea water coolant flow through turbine island	~45 m^3/s
Planned duration of commercial operation	60 years



Event identification and categorization

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- Initial, extensive list of site-specific external events was compiled based on YVL B.7 and international guides and standards (such as IAEA SSG-3)
  - The initial list included 73 events related to meteorology, ground, water bodies and human actions (only accidental events)
- The events were categorized based on the significance to nuclear safety (graded approach)

Category	Approach	Examples
I. Events significant to nuclear safety	• Detailed evaluation • Determination of design values • To be considered in plant design and analyses	Tornado, high sea water level, oil spill in the sea, earthquake
II. Events with low significance to safety	• To be considered in plant design	Air pressure, drought, soil frost
III. Events with no safety significance	• Not considered (explicitly)	Sand storm, avalanche, industrial accidents

Probability evaluation

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External events	Evaluation method
Air temperature and enthalpy, lightning stroke peak current, precipitation, freezing rain, snow load and depth, wind, tornado, downburst, sea water level and temperature	Hazard curves based on measurement data (supplemented with human observations and climate simulation)
Algae, frazil ice, pack ice, oil spill and other events endangering sea water supply	Evaluation based on operational history of nearby power plants. Separate evaluation for oil spill based on accident history in the Baltic Sea[1].
Waves (together with high sea water level)	Wave run-up and overtopping assessment
Airplane crash (accidental)	Specific evaluation based on flight data
Earthquakes	Comprehensive seismic probabilistic hazard assessment
Loss of offsite power	Probability evaluation for LOOP due to external events (and technical failures)[2]

[1] J. Helander. *"Maritime oil spill risk assessment for Hanhikivi nuclear power plant"*, PSAM 12, Honolulu, 2014.
[2] M. Biese. *"Loss of offsite power frequency estimates due to external events at a Finnish nuclear power plant"*, PSAM 14, Los Angeles, 2018.

Event combinations

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- Discussed in: J. Helander. *"Identification and Analysis of External Event Combinations for Hanhikivi 1 PRA"*, PSAM 13, Seoul, 2016.

Design values for external events

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- General approach based on Finnish YVL guide B.7 requirements
  - events with median probability ≥ 10^{-5} /y to be considered as design basis events
  - events with median probability 10^{-5} /y - 10^{-7} /y to be considered as design extension conditions
  - adequate margin to record observations
  - effect of climate change is considered

External event PRA

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- Preliminary PRA for Hanhikivi 1 including external events completed in 2017
  - Some design and layout information based on reference plant information
- All safety significant external events (category I) and relevant event combinations were considered in PRA
- When possible, external event consequences are assessed at different levels
  - Events below the design level (> 10^{-5} /y)
  - Events between design level and design extension condition level (10^{-5} - 10^{-7} /y)
  - Events above design extension condition level (< 10^{-7} /y)
  - Screening limit 10^{-9} /y
- Seismic PRA is based on generic fragilities of component types

External event PRA

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- Based on preliminary PRA results, the contribution of earthquakes and other external events to core damage frequency is 13 %
- The following external initiating events are considered most significant
  - Earthquakes
  - Loss of sea water cooling
  - Lightning
  - Event combinations: strong wind + snow storm, strong wind + low sea water level
- Development needs:
  - More detailed evaluation of consequences based on Hanhikivi 1 specific information
  - Using less conservative assumptions

Summary and conclusions

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- A systematic approach to identify and evaluate external events is essential
  - The use of national and international expertise is important (for example Finnish Meteorological Institute, Institute of Seismology)
- Probability evaluation includes challenges
  - Lack of data and extrapolation up to 10^{-9} /y
  - Evaluation of event dependencies
  - ➢ The uncertainties shall be realistically considered in PRA
- According to the preliminary PRA of Hanhikivi 1, the risk related to external events is small (because even extreme events are considered in the plant design)